Section Life Cycle Management

Editorial

Life-Cycle Based Methods for Sustainable Product Development

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Abstract. Sustainability – a term originating from silviculture, which was adopted by UNEP as the main political goal for the future development of humankind – is also the ultimate aim of product development. It comprises three components: environment, economy and social aspects which have to be properly assessed and balanced if a new product is to be designed or an existing one is to be improved. The responsibility of the researchers involved in the assessment is to provide appropriate and reliable instruments. For the environmental part there is already an internationally standardized tool: Life Cycle Assessment (LCA). Life Cycle Costing (LCC) is the logical counterpart of LCA for the economic assessment. LCC surpasses the purely economic cost calculation by taking into account hidden costs and potentially external costs over the life cycle of the product. It is a very important point that different life-cycle based methods (including Social Life Cycle Assessment) for sustainablity assessment use the same system boundaries.

Keywords: Brundtland report; ecoefficiency; economic life cycle assessment (LCC); environmental life cycle assessment (LCA); industrial ecology; integrated product policy; life cycle management (LCM); product-related life cycle assessment; social life cycle assessment (SLCA); sustainability; United Nations Conference of Environment and Development (UNCED)

1 Objective

Sustainability is a broad and not precisely defined term, a guiding principle or goal laid down by the United Nations Conference of Environment and Development (UNCED) in Rio de Janeiro, 1992. In order to fill this principle with life, all sectors of society in all countries have to redirect their activities, which presently nearly exclusively aim at (economic) growth. In this article, product development is in the focus of the analysis. It is hoped, however, that also other fields of economy and society can profit from ideas conceived for a rather narrow sector of human activities. It should be noted that similar concepts have been put forward, as Life Cycle Management, Ecoefficiency, Integrated Product Policy, and Industrial Ecology, which try to achieve sustainability or at least to move in the right direction. The problem for responsible decision makers consists in weighting different approaches, technologies, product lines, etc. within an increasingly global business world. It is the duty of researchers and experts of different fields to develop and improve methods that can be used to operationalize the guiding principle of sustainability. What is ultimately required are simple-to-use (but not necessarily simplistic!) methods which give reliable results as a basis for decisions at different levels of the society (industry, politics, etc).

2 Sustainability

The term 'sustainability' (in German: 'Nachhaltigkeit') originates from silviculture and means that only as much wood is removed from the forests as grows again in the long run [1]. Cultivation and care are the prerequisites of sustainable forestry. Hans Carl von Carlowitz, the founder of this practice, recognized well the economic and social implications of his idea (in his main profession, he was the superintendent of the Saxonien silver mines in the early 18th Century). He therefore may also be considered as the father of sustainability in the modern sense of the word. In the global political arena, the term sustainability became renowned by its use in the report 'Our Common Future' by the World Commission on Environment and Development, better known as 'The Brundtland Report' [2]. In this report, environmental protection is linked with global development and emphasizes the responsibility humankind has for future generations. This can be recognized in the famous definition: 'Sustainable development is development that meets the needs of present without compromising the ability of future generations to meet their own needs'. There is a high moral claim in this principle and a lack of guidance, how this aim can be reached.

At the United Nations Conference of Environment and Development (UNCED) in Rio de Janeiro, 1992, sustainable development was laid down as the most important task of the 21st century. Moreover, in Agenda 21 many political and industrial areas were analyzed with regard to sustainable development and possible improvements have been presented. From here on it has been clear that three aspects (the three 'pillars' of sustainability) have to be considered and brought together: Ecology (Environment), Economy, and Social aspects.

There seems to be a consensus about these three pillars, but not about the relative weights of these aspects. Industrialized countries tend to emphasize the environmental aspect (at least the green movements, the environmental agencies, and some companies as well), whereas developing countries give highest priority to economic development. As understandable these different priorities may be, they undermine the spirit of Bro Harlem Brundtland's and UNCED's conception. What is needed from a methodological point of view – that's the field where researchers can and should contribute – are assessment methods allowing to distinguish between developments which are more or less sustainable and those which are not at all. The results of studies based on such methods could be used by decision makers to make the right decisions. Concentrating on products (including serv-

ices) in the following, I hope to show that we are not starting at zero, since several methods already exist, which have to be refined and combined.

3 Life Cycle Methods

3.1 Why life-cycle based?

Any environmental, economic, or social assessment method for products has to take into account the full life cycle from raw material extraction, production to use and recycling or waste disposal. In other words, a systems approach has to be taken. Only in this way, trade-offs can be recognized and avoided. Life cycle thinking is the prerequisite of any sound sustainability assessment. It does not make any sense at all to improve (environmentally, economically, or socially) one part of the system in one country, in one step of the life cycle, or in one environmental compartment, if this 'improvement' has negative consequences for other parts of the system which may outweigh the advantages achieved. Furthermore, the problems shall not be shifted into the future [2]. The second point is that life cycle thinking is not enough, since in order to estimate the magnitude of the trade-offs, the instruments required have to be as quantitative as possible. Since we are living in a global economy (which from the European perspective started in the 15th century, not as recently as often claimed), the system boundaries used in the methods have to be global as well. In this context, the life cycle initiative jointly launched by UNEP and SETAC deserves high attention and support [3].

3.2 Environmental life cycle assessment (LCA)

Product-related life cycle assessment with an emphasis on energy, resources, and waste started around 1970 [4–6]. It was the time of 'The Limits to Growth, a report to the club of Rome' [7] and the first oil crisis soon afterwards showed, if not the shortage of oil, but the vulnerability of the global economic system. Twenty years later, LCA (now officially under this name) was developed by SETAC [8,9] and later on standardized by the International Standardisation Organisation (ISO 14040-43; TR 14047,49; TS 14048). The first round has been finished [10] and LCA can now be considered to be the first and only internationally standardized environmental assessment method.

The basic principles of LCA, which together distinguish this method from other environmental assessment methods, are:

- The analysis is conducted 'from cradle to grave'
- All mass and energy flows, resource and land-use, etc., and the potential impacts connected with these 'interventions', are set in relation to a 'functional unit' as a quantitative measure of the benefit of the system(s)
- LCA is essentially a comparative method (also improvements of one system are compared to the status quo).

In short: two or more systems are compared on the basis of a common benefit in a 'holistic' way. The advantage of (at least theoretical) completeness is partly set off by the uncertainty where and when exactly some of the processes, emissions, etc. occur and which ecosystems or how many humans may be harmed, and whether or not thresholds of effects are really surpassed. Furthermore, the magnitude of the functional unit is usually fixed arbitrarily in wide margins; for instance, the functional unit for comparing different containers for beverages may be the filling of 1, 100 or 1000 liters (but not 1 bottle or barrel!). As a consequence, the absolute amounts of the 'interventions' have no meaning and concentrations of emitted substances cannot be calculated. The additional use of other, often complimentary – albeit not standardized – methods (e.g. risk assessment, material and substance flow analysis) has therefore been recommended for the sake of decision-making [11].

One advantage of standardization is that LCA has a clear structure, which essentially goes back to SETAC [9], and now consists of the following four components (ISO 14040): Goal and scope definition, Inventory analysis, Impact assessment, and Interpretation (formerly Improvement assessment [9]). If comparative assertions (system A better than or equal to system B) are made available to the public, a 'critical review' is mandatory (ISO 14040 § 7.3.3) [12]. This and many other 'obstacles' were built in the ISO-series of LCA standards in order to prevent the misuse, especially by false claims based on sloppy LCAs. As a consequence of these preventive measures, a full LCA to be used publicly has become a somewhat lengthy procedure. Of course, the learning process, which is perhaps more important than the numerical results, is more rewarding in a long and carefully conducted LCA study compared to a 'quick and dirty' one. On the other hand, during the design phase, there is not much time and therefore simplified methods were proposed and also compared with each other [13]. In 'Design for environment', a compromise has to be found between a reasonably comprehensive coverage of the life cycle and the time needed for data collection and modeling. The actual calculation process is fast due to the elaborate LCA software, which is available nowadays.

3.3 Economic life cycle assessment (LCC)

The economic counterpart of LCA is known under several names, as Life Cycle Costing (LCC), Full Cost Accounting (FCA), Total Cost Assessment (or Accounting) (TCA) [14-16]. Also conventional cost accounting of products includes life cycle aspects, since the costs of raw and intermediate materials enter into the calculation. Costs involved in the use of products and in waste removal, or recycling, generally do not show up (with the exception that in special cases the producer may have to take back the product or pay for the waste collection, as in the case of the German 'Green Dot' system). The main difference between conventional cost accounting and LCC or TCA consists in accounting for 'hidden' or 'less tangible' costs, including costs for environmental protection [14,17]. Of course, also these costs are included in conventional cost accounting, mostly in the form of overheads, but they are not attributed clearly to a specific product system. As in LCA, this clear attribution to a product system is important for assessment in order to estimate the true costs (LCC) or true environmental interventions (LCA) of the product (system) to be compared with another one which fulfills the same function or has the same benefit.

White et al. define Total Cost Assessment as the 'long-term, comprehensive analysis of the full range of internal costs and savings resulting from pollution prevention projects and other environmental projects undertaken by a firm' [14]. In this method, the economic benefits of pollution control measures are also included, whereas in conventional accounting only the costs of pollution prevention would be taken into account. This inclusion of positive trade-offs clearly indicates life cycle thinking. The term 'life cycle', however, is often defined in another way in the economic sciences, namely as the sequence product development – production – marketing/sale – end of economic product live; as noted by Norris [15], this economic 'life cycle' may be even shorter in some products than the physical life cycle ('cradle-to-grave') used in LCA. In a further step, even the external costs due to environmental damages connected with the products may be included [14,17]. These costs are not incurred to the company, but rather to society or even to future generations. The quantification of these costs is difficult, since it is often not clear, which damages are – or will be in future – connected to the interventions caused by a product system. Furthermore, some damages (e.g. ethical and esthetic ones) cannot be expressed in monetary terms or even the attempt to monetarize sounds clearly repulsive (what is the monetary value of a human?). There is also the problem of double counting if LCA and LCC is applied, and LCC includes external effects. In this case, the external costs are expressed in monetary units and in 'environmental units', i.e. in impact category indicator results according to ISO 14042 or in 'ecopoints', etc.

3.4 Social life cycle assessment (SLCA)

SLCA is the least developed life cycle method, indicating a research gap. O`Brian et al. described an attempt to combine SLCA with (E)LCA to a method called 'Social and Environmental Life Cycle Assessment' (SELCA) [18]. It is interesting to note that the purpose of this integration was quantifying sustainability. SLCA, according to these authors, consists of the components 'Problem definition scoping', 'Data analysis', 'Process assessment', 'Evaluation', and 'Action'. Data analysis is equivalent to Inventory analysis, Process assessment to Impact assessment. Although it seems difficult to combine concepts and data from different fields as sociology and technology, it is clearly worth trying. It should be mentioned that the German 'Product Line Analysis', basically an early LCA, also includes economic and social assessment components [19].

4 Conclusions

I hope to have shown that only life cycle based methods have the potential for sustainability assessments. The methodological problem consists in combining the existing and new methods into one suitable instrument. It should be noted that equal and consistent system boundaries have to be used for environmental, economic, and social life cycle assessment. It is suggested that the physical rather than the economic life cycle definition is used throughout. A lucid analysis of LCA and LCC with the aim of combining them to create an assessment tool for supply chain management has been presented by Rebitzer [20]. Including social assessment, as proposed by O`Brian et al. [18], could pave the way to a true sustainability assessment including the three main aspects of sustainable development.

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